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LEAD-CONTAMINATED SOIL DISPOSAL IN NON-HAZARDOUS WASTE LANDFILLS—GROUNDWATER EFFECTS AND POLICY IMPLICATIONS

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ABSTRACT

Lead-contaminated soil that fails the Toxicity Characteristic Leaching Procedure ("TCLP") test must be managed as hazardous waste under the Resource Conservation and Recovery Act ("RCRA") and disposed in Subtitle C landfills. We examine the actual risk lo groundwater from the management and disposal of lead-contaminated soil in non-hazardous waste landfills. Lead concentrations in leachate-affected groundwater were modeled using EPA's Monte Carlo Composite Model for Leachate Migration with Transformation Products ("CMTP"). Simulated leachate concentrations were based on Synthetic Precipitation Leaching Procedure ('SPLP') and TCLP tests of soil from lead-contaminated Superfund sites. Receptor well lead concentrations' were less than the drinking water standard (0.015 mg/L) in 98.5% of the SPLP scenarios. and 96% of the TCLP scenarios. Thew, were more protective than the level EPA used to justify a proposed conditional exclusion from the RCRA hazardous waste program for architectural debris containing lead-bearing paint. allowing disposal of such debris in non-hazardous waste landfills. Since the *risks* to groundwater from lead-contaminated soil disposal are less than those from architectural debris. EPA should allow leadcontaminated soil that fails the TCLP to be disposed in non-hazardous waste landfills. This would reduce the costs of its management and encourage greater remediation of lead soil hazards.

Key **Words**: Lead, soil contamination. soil disposal, groundwater. leachate, leaching tests

INTRODUCTION

On December 18, 1998, EPA proposed two rules: the Temporary Suspension of Toxicity Characteristic Rule for Specified Lead-Based Paint Debris (63 Fed. Reg. 70233) and the Management and Disposal of Lead-Based Paint Debris (63 Fed. Reg. 70190). The effect of these proposed rules would be to authorize the management of lead-based paint ("LBP") debris under TSCA management standards rather than under more expensive RCRA Subtitle C hazardous waste regulations. The proposed TSCA management standards provide a less rigorous and hence less costly management regime for generators of LEP by, among other things. allowing disposal in construction and demolition ("C&D") landfills.

The proposed rules arc supported by a groundwater pathway analysis conducted by EPA (1998). The analysis used EPA's Composite Model for Leachate Migration with Transformation Products ("CMTP") model to demonstrate that disposal of LBP debris in C&D landfills would pose little risk of contamination to groundwater supplies. That approach involved the computation of lead concentrations in receptor wells resulting from landfill leachate. The CMTP was used to

simulate hypothetical cases to develop a statistical picture of the likelihood of lead concentrations exceeding the drinking water standard of 0.015 mg/L.

EPA examined two scenarios: 1. Disposal of LBP debris in municipal solid waste ("MSW") landfills. and 2. Disposal of LBP debris in C&D landfills. Under both scenarios. the landfills were assumed to be unlined (EPA. 1998. p. 39). The scenarios differed only in the character of the leachate. Under the first scenario. leachate concentrations were derived from Toxicity Characteristic Leaching Procedure ("TCLP") tests. The TCLP test leaches ground waste samples with an acetic acid solution (pH=5) to simulate the effect of municipal solid waste landfill environments (i.e., compaction and organic acids released by decaying garbage).

Under the second scenario. leachate concentrations were derived from Synthetic Precipitation Leaching Procedure ("SPLP") tests. The SPLP test leaches solid waste samples with an acid solution that simulates the effect of acid rain. It is less aggressive than TCLP. in pan because it uses higher pH levels. and generally produces lower lead concentrations in the leachate. It is considered more appropriate' for non-municipal solid waste landfill environments because these landfills ordinarily do not receive garbage that would generate organic acids (EPA, 1998. p. IS).

This repon examines the risks of the management of lead-contaminated soil under the TSCA program and, in panicular. the risks From disposal in C&D landfills. We model the effect of using SPLP lead concentrations to represent leachate concentrations from C&D landfills in simulating lead concentralions at receptor wells. SPLP concentrations are intended to provide a realistic estimate of risk. For comparison, we also model TCLP lead concentrarions from lead-contaminated soil,

METHODS AND DATA SOURCES

Our principal aim was to compare the risks from disposal of lead-contaminated soil with those from the disposal of LBP debris under the same condirions. EPA's assessment of groundwater leachate was based on TCLP and SPLP leachate concentrations obtained from 41 architectural debris samples (EPA. 1998. Table 2.7). These measured concentrations were used to estimate statistical distributions for inputs into the CMTP model.

We obtained bulk lead concentrations and TCLP and SPLP leachate concentrations from as many lead-contaminated soils as feasible. These were developed from review of technical reports on sites known to be heavily contaminated by lead. The sites include battery breaking yards, smelters. mines. a brass foundry. and a ceramic tile factory. The data set includes 153 analyses From 17 'separate sites. Analyses include soil from source areas and. in some cases. from surrounding areas. but exclude ore concentrates. slag. and other non-soil materials. Of these analyses. 115 samples From 13 sites had measured TCLP concentrations. and 33 samples from 6 sites had measured SPLP concentrations. Eight samples had both TCLP and SPLP concentrations analyzed. Concentrations. locations. .and other information on sample rites are tabulated in BCI (1999).

The cumulative frequency distribution of lead concentration in the soil samples is shown in Figure 1. Concentrations range over almost three orders of magnitude. from 30 mg/kg to 28,600 mg/kg. The lowest concentrations are in the range

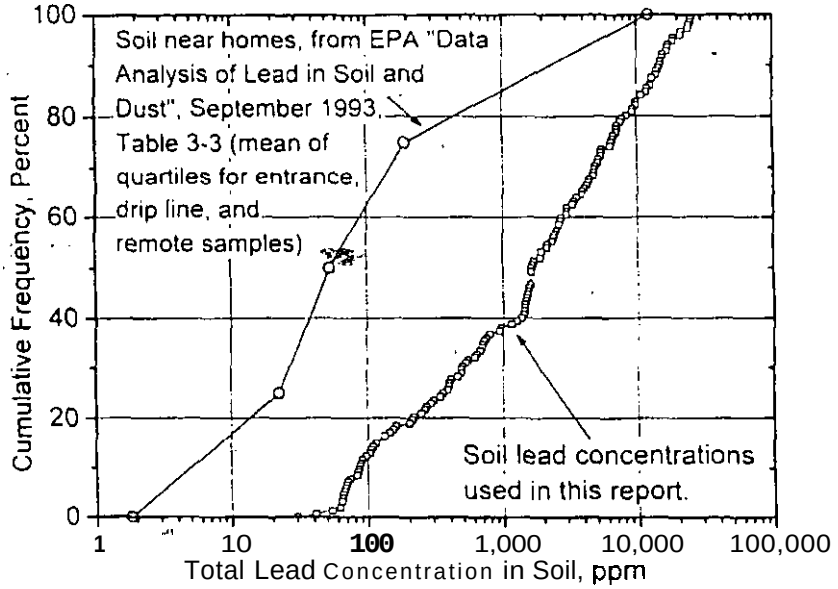

FIGURE 1
Frequency Distributions of Lead Concentration in Soil

TABLE 1
Comparison of TCLP and SPLP Lead Concentrations

TCLP LEAD (mg L)	SPLP LEAD (mg L)	SPLP/TCLP Ratio
0.25	0.04	0.16
0.39	0.11	0.282
1.3	0.11	0.085
3.7	0.1 1	0.03
14	0.1 1	0.008
20	0.11	0.006
26	0.14	0.005
144.6	0.26	0.002

of natural l& concentrations in crustal rocks. from 16 to 80 mg/kg (Hem. 1985. Table 1). and probably represent uncontaminated soil.

For comparison. the figure also shows the distribution of lead in soil near residences. These concenmtion data were obtained bv a nationwide study of hazards from lead-bearing paint in housing (EPA, 1993, Table 3-3). Lead concentrations in the residential soil samples are between 9 and 40 times smaller, for the same percentile, than in the soil samples presented here. This indicates that the samples used in this report represent the most contaminated soil likely to be encountered and, therefore. that lead-contaminated soils from residences are likcly to pose much less risk.

Lead Concentrations In Soil And LBP Debris Leachate

SPLP lead concentrations from the lead-contaminated soil were compared to the distribution of SPLP concentrations from LBP architectural debris used in EPA's CMTP model (EPA. 1998, Table *2.9).* Cumulative frequency distributions of both sets of SPLP concentrations are shown in Figure 2. At most percentile levels, soil SPLP concentrations were one-tenth or less of the corresponding SPLP concentrations from architectural debris. This is due in part to the geochemical properties of soil that cause it to adsorb lead and thus retard its mobility. Soil SPLP concentrations were more variable than debris SPLP concentrations. ranging over more than two

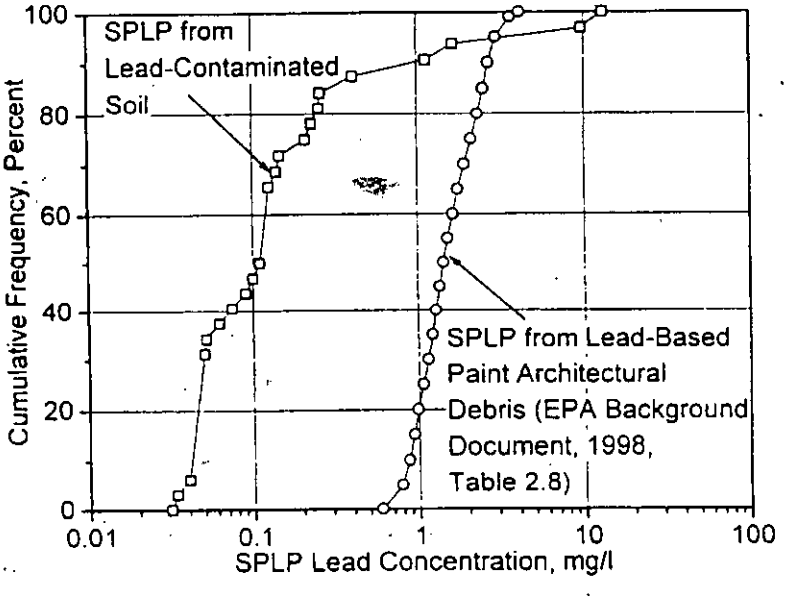

FIGURE 2
Frequency Distributions of SPLP Lead Concentrations from Soil and LBP Debris

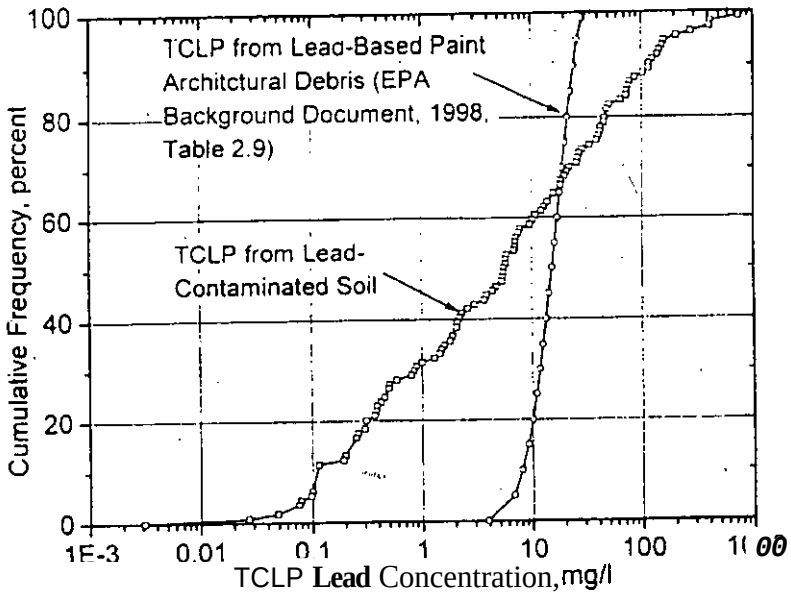

FIGURE 3
Frequency Distributions of TCLP Lead Concentrations from Soil and LBP Debris

orders of magnitude as compared to one order of magnitude. This is probably due to the wide range of lead-bearing materials that can contaminate soil. as compared to the narrower range of compositions of lead-bearing paint.

Similarly. TCLP lead concentrations from the lead-contaminated soil were compared to the distribution of TCLP from LBP architectural debris (EPA. 1998. Table 2.9). Cumulative frequency distributions of both sets of TCLP concentrations are shown in Figure 3. Soil TCLP concentrations were much more variable than debris TCLP concentrations, ranging over between five and six orders of magnitude as compared to one order of magnitude. Maximum soil TCLP concentration was about 3.000 times greater than the maximum TCLP concentration from architectural debris. About one-third of the soil TCLP concentrations were greater than the maximum From debris.

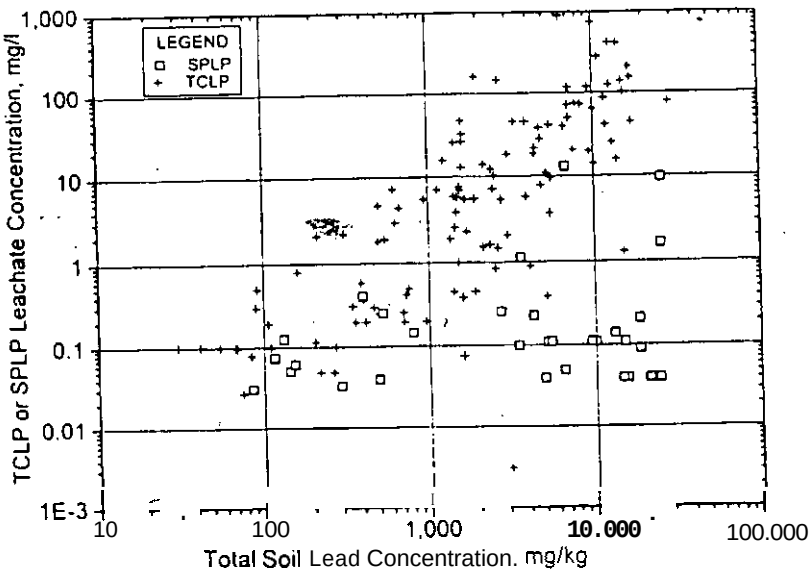

FIGURE 4
SPLP and TCLP Lead Concentrations vs Soil Lead Concentration

Sd SPLP and TCLP lead concentrations are plotted against soil lead concentration in Figure 4. (Many of the lowest concentrations represent detection limits. and thus overestimate the actual lead concentration.) SPLP concentrations appear to have a modest upward trend throughout the range of soil lead concentrations and become more variable at high soil lead concentrations. Throughout the entire range, however, most SPLP concentrations are low, less than 1 mg/L.

TCLP concentrations increase with soil lead concentration. This increase. as compared with the small increase in SPLP concentrations, reflects the greater chemical aggressiveness of TCLP at extracting lead From soil. TCLP data haw a large degree of scatter, over about two orders of magnitude at any given soil concentration. Consequently. prediction of TCLP concenmtion on the basis of total soil lead concentration is not accurate.

The difference in leachate lead concentrations between SPLP and TCLP can be large. EPA has observed that the lead concentration in leachate from LBP debris samples subjected to the SPLP was approximately 1/10 the lead concentration in leachate measured under the TCLP (63 Fed. Reg. 70200). The disparity is even greater for lead-contaminated soil. Median TCLP lead concentration from soil was 5.5 mg/L, and median SPLP concentration was 0.11 mg/L. Thus, for soil, lead in SPLP leachate was 1/50 the lead concentration in TCLP leachate. Table 1 compares SPLP and TCLP for soil samples where both were performed. Six of the eight analyses showed SPLP lead to be less than 1/10 of the TCLP concentration.

The large observed difference between SPLP and TCLP concentrations is principally due to lead's sensitivity to the acetic acid leaching solution used by the TCLP. The relatively high leachability and solubility of lead under the TCLP is not likely to be representative of lead's behavior under most environmental conditions affecting its movement after leachate exits a landfill.

Leads mobility in the environment is generally low. McCulley, Frick & Gilman (1991, p. 31) and EPA (1999) reported that a number of retarding mechanisms bind lead to soil and greatly slow its movement with groundwater. This occurs where lead compounds have low solubility. so that lead precipitates as solid compounds within the soil. Naturally-occurring clays also can adsorb lead at pHs ranging from mildly acidic to basic. If iron and manganese oxides are present, they can adsorb lead at acidic pHs. Solid organic materials also can adsorb lead at acidic to mildly basic pHs.

The CMTP Model

The risk to groundwater posed by disposing lead-contaminated soil in conventional landfills was estimated by simulating a large number of possible scenarios and examining BE resulting lead concentrations in hypothetical monitoring wells. The CMTP model was specifically designed for simulating groundwater contamination scenarios in the context of nationwide rule m'aking. It simulates the movement of contaminants from the bottom of the landfill waste. downward through the unsaturated zone to the water table. and then horizontally by way of groundwater flow to a receptor well. The concentration of the leachate exiting the bononi of the landfill is one of the principal inputs to the model.

Results From the CMTP consist of statistical distributions of lead concentration in' a hypothetical receptor well. The location of the well with respect to the landfill is randomly selected from a user-specified statistical distribution. The output distributions, shown as graphs or tables. show how likely the lead concentration is to exceed health-based standards.

The CMTP input values used for the simulations of disposal of lead-contaminated soil came From two general sources:

- Data generated for this study. Values of leachate lead concentration, soil lead concentration. and soil thickness that characterize proposed disposal of lead-contaminated soil were determined specifically for this investigation and are listed in BCI (1999). Appendix A. They differ from the values used in EPA's analysis of disposal of architectural debris (EPA. 1998).
- Data the same as in EPA's modeling. Certain data are used for the majority of applications of the CMTP. and are built into the model's program code. Examples include distributions of infiltration rate and groundwater velocity. Hence, the values of such data used in this investigation were necessarily the same as those used by EPA in modeling leaching of lead from LBP architectural debris (EPA, 1998). In addition. the characteristics of landfills where disposal is proposed are also the same as were used by EPA (1998). These characteristics are identified in Appendix A of EPA (1998). They include. for example, landfill area and the distance to the nearest receptor well. Data representing these characteristics are read from external data files. but were kept the same as in the data files used by EPA (1998).

The CMTP uses the lead concentration of disposed soil in calculating the mass of lead in the soil. This mass is used. together with the leachate concentration. to calculate the time over which lead leaching takes place. The soil lead concentration is not entered directly. to improve the speed of the CMTP (EPA. 1996a, pp. 8-17). Instead. the ratio between soil concentration (in mg/kg) and leachate concentration (in mg/L) is entered (EPA. 1997. pp. A-8 - A-9). This ratio is referred to as "C_w/C_t," and has units of L/kg. Although the CMTP can include up to nine such ratios in a single model run. only a single ratio was used for modeling lead-contaminated soil. as was done for LBP architectural debris (EPA. 1998. p. 21). This ratio was calculated by dividing the mean total soil lead concentration (averaged over samples having a TCLP or SPLP value) by the mean TCLP or SPLP concentration. The' ratios are 89.1 L/kg for TCLP. and 31.631 L/kg for SPLP.

MODELING SCENARIOS AND RESULTS

We examined two scenarios that represent a realistic simulation of the risks of disposing lead-contaminated soil:

disposal in C&D landfills, and disposal in municipal solid waste landfills. In both scenarios, the landfills were assumed to be unlined, as was assumed by EPA (1998, p. 39). The scenarios differed only in the frequency distribution representing leachate concentration.

Scenario I: C&D Landfills (SPLP)

In Scenario 1, a cumulative frequency distribution was derived from the corresponding SPLP lead concentrations. This distribution is shown in Figure 2. The SPLP distribution was used as the CMTP input ("CZERO") representing concentration of leachate exiting the bonom of the landfill. It should be noted that most of the SPLP lead concentrations from soil shown in Figure 2 are much less than the corresponding SPLP concentrations from LBP debris. This suggests strongly that receptor-well lead concentrations From lead-contaminated soil disposal would be generally lower than those from LBP debris disposal, which EPA considers to be safe (63 Fed. Reg. 70190). The strong nonlinearity of the lead isotherms used by the CMTP model, however, makes it hard to estimate exactly how much lower the concentrations would be. Therefore, it was necessary to actually run the CMTP model.

Use of SPLP to approximate leachate concentrations From C&D landfills is consistent with EPA guidance. EPA suggests the use of SPLP for evaluating risks when contaminated soil is disposed of in landfills other than municipal landfills. This guidance states that the SPLP was developed to model leaching by acid rain and is generally appropriate for contaminated soil (EPA, 1996b, p. 30). EPA reiterated its preference for the SPLP test under the circumstances considered here in its proposed regulations for disposal of LBP debris (63 Fed. Reg. 70199-70200).

The principal results of the CMTP simulation using SPLP data are shown in Figures 5 and 6. The cumulative frequency distribution in Figure 5 represents the peak simulated lead concentration at a downgradient receptor well within a 10,000 year simulation period. Approximately 98.5% of the peak simulated lead concentrations are less than the drinking water standard of 0.015 mg/L. This percentage is above EPA's target range for levels of protectiveness of 85% to 95% (63 Fed. Reg. 70203). It also exceeds the level of protectiveness of

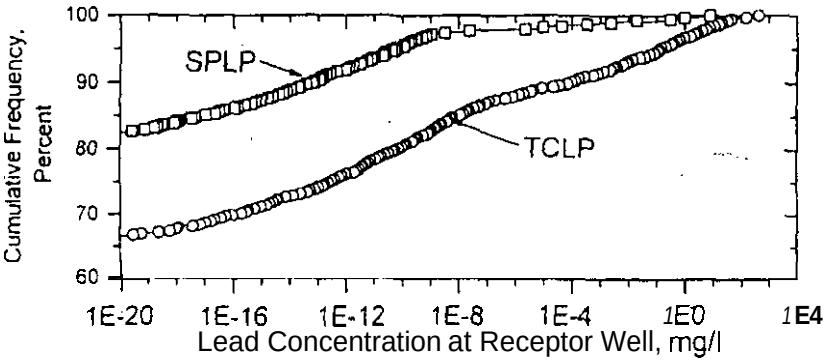

FIGURE 5
Distribution of Peak Lead Concentration at Receptor Well

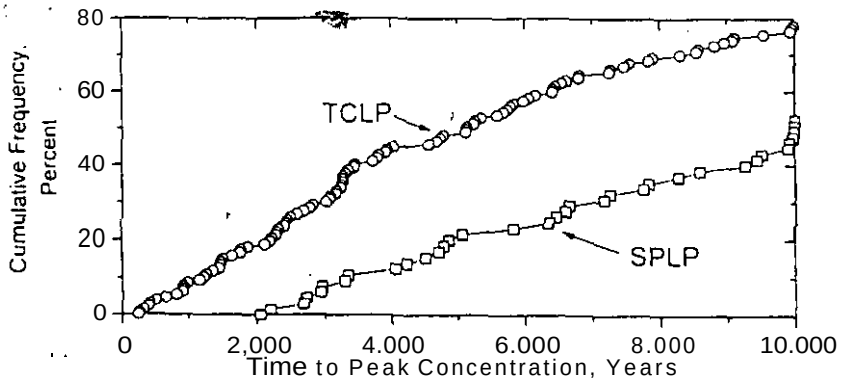

FIGURE 6
distribution of Time to Peak Where Peak Concentration > 0.015 mg/l

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95% resulting from EPA's CMTP modeling of disposal of LBP debris (63 Fed. Reg. 70203).

When the peak concentration occurs also is of interest. Figure 6 shows the distribution of times ai which the peak simulated lead concentration occurs in a receptor well. considering only the 1.5% of all cases in which the drinking water standard of 0.015 mg/L was exceeded at the well. None of the peak concentrations occurred less than 2.000 years after deposition of the lead-contaminated soil. About half of the peaks occurred after the end of the 10,000 year simulation period; that is. lead concentrations were still increasing at that time.

Scenario 2: MSW Landfills (TCLP)

Scenario 2 was carried out io test the effect of using extremely high (conservative) leachate input concentrations. Scenario 2 used TCLP lead concentrations in place of SPLP concentrations; model conditions were otherwise the same. The cumulative frequency distribution of TCLP lead concentrations is shown in Figure 3.

The principal results of the CMTP simulation are shown in Figure 5. Approximately 4% of the simulated lead concentrations at a downgradient receptor well exceed the drinking water standard of 0.015 mg/L within the 10.000 year simulation period. This is slightly less than the percentage of exceedances (4.5%) cited by EPA (1998, p. 22) in its justification of disposing LBP architectural debris in C&D landfills using SPLP concentrations. This scenario therefore appears to be at least as protective.

Figure 6 shows the distribution of times at which the peak simulated lead concentration occurs in a receptor well, considering only the 4% of all cases in which the drinking water standard of 0.015 mg/L was exceeded at the well. However. none of the peak concentrations occurred until 287 years after dkposition of the lead-contaminated soil. About 91% of the peakr occurred later than 1,000 years. and about 80% later than 2.000 years. Approximately 26% of the peaks occurred after the end of the 10,000 year simulation period.

CONCLUSIONS

Based on the results of our modeling, we conclude that disposal of lead-contaminated soil in non-hazardous waste landfills is environmentally acceptable. Even under the extremely conservative assumption that lead leachate concentrations would be as high as from TCLP leachates. disposal of lead-contaminated soil in municipal solid waste landfills would pose less risk than disposal of LBP debris as proposed by EPA. Based on these results. EPA's regulation of lead-bearing soil under the RCRA hazardous waste program is unnecessary. This analysis shows that the management of lead-bearing soil in non-hazardous landfills under the TSCA program is acceptable. reliable. and protective of human health and the environment.

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